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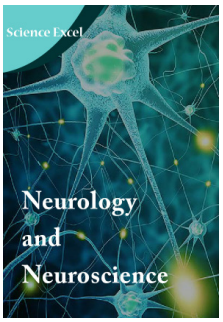

Biological Versus Artificial Consciousness: Will The Two Ever Meet?

Wolfgang Kromer

Abstract

The present opinion article first discusses the fundamental basis of self-consciousness (self-awareness). The biological situation is then compared to artificial systems. Actually, the deficiencies of artificial systems will highlight the key features of biological systems.

Biological self-consciousness requires an individual to whom something can become conscious, which basically depends on the organism's ability to distinguish between sensory input from its environment versus its body (embodiment). As any software only provides the tools for processing input, but does not per se substitute for embodiment, applying the above principle to an artificial system would require its "body" (hardware inclusive of the robot's encasement and its functional parts) being equipped with a complex sensorium penetrating the whole material. Moreover, input from the latter would have to be distinguished by the software from any environmental input, and the hardware's sensorium would have to be capable to communicate with the software in a bidirectional manner similar to the biological situation. Also, the artificial system would have to be able to integrate these "bodily" signals such that they are "experienced" as all belonging to one and the same "individual" entity, as it is the case in a biological system. It is considered unlikely to meet such highly complex requirements in a dead material.

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A Hot Topic Still Unsolved

Will the two ever meet? This would require that both of them actually exist. Although we certainly agree on self-consciousness to exist in biological systems, but how about artificial systems? Before starting, let us first clarify what we will talk about. Be it biological or artificial (machine) consciousness, the terms consciousness and self-consciousness are used in the present article interchangeably in the sense of being aware of one's existence, just as the terms self-recognition, self-awareness or I-consciousness. By artificial systems, any computer systems (composed of hardware and software) are meant that either are, or are not, functionally connected to a robot body with functional capabilities. Biohybrid systems [1] are beyond the scope of the present article as their currently restricted application focus seems to be too far away from the generation of self-consciousness. However, the latter would require the same preconditions to be fulfilled as will be discussed in this article for a dead material.

"Still wanted – the mechanisms of consciousness!" is the title of an editorial by Aru and Bachmann [2]. It refers to biological consciousness. Will it wait in vain for its artificial counterpart? Krauss and Maier [3] noted in their review on conscious machines and on theories of consciousness in general "that there are neural network architectures from which base consciousness could emerge. Yet, there is still a long way to form human-like extended consciousness". Blum and Blum [4] went one step further by answering the "big question: Will CTM [Conscious Turing Machine] have the 'feeling' that it is conscious? While we believe that the answer is YES, at least for 'sufficiently complex' CTM, we cannot prove anything mathematically without a definition of the 'feeling of consciousness', which we do not have (yet)". Against the background of this obvious uncertainty, the present article will address the crucial question: What may be the fundamental prerequisite which a biological or artificial system must meet in order to develop self-consciousness?

Biological Systems: The Basics

The literature lists quite a number of attributes of consciousness, such as active representation, global (cerebral) competition between representations, reentrant processing, attention, anticipation, action control and intentional states, learning and problem solving (see: for example: [5-7]). All of them and many others shed some light on particular aspects of consciousness, but none of them does contribute to anything reasonably called self-consciousness without one fundamental precondition: The speech is about the ability of the organism to recognize its existence as an individual opposed to the external world. Only then will cerebral functions, addressed by the above attributes, further develop and shape this self-perception. What is this ability about?

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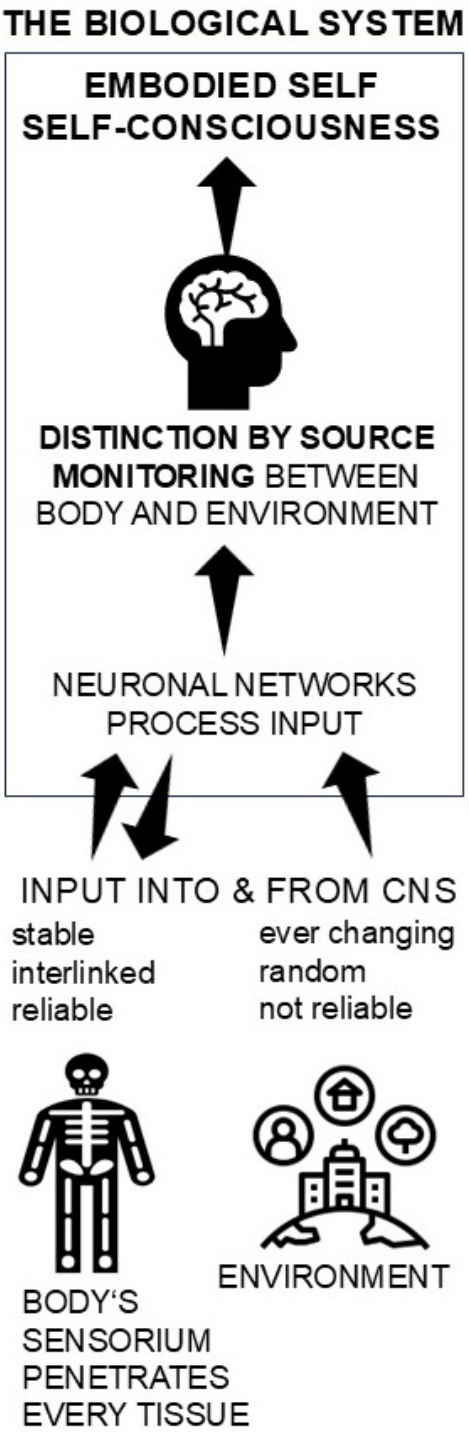

Figure 1. Biological consciousness depends on the comparative representation of bodily versus environmental signals. Source monitoring between the two sources of information enables the brain to constitute its self, based on the distinguishable features of bodily stimuli (stable, interconnected and therefore reliable) as compared to stimuli of environmental origin (changeable, random and therefore not reliable). CNS = central nervous system.

The bottom of all is that, to become an individual, a stable reference system is required which the organism can rely on in order to constitute its self. This competence depends on a comparator function to discriminate between the own body and the outside world [8-10] as illustrated in Figure 1.

Comparator functions are operative at various levels in the central nervous system (see, for example: [11-13]). The "Source Monitoring Theory" by Kunzendorf [14] introduced such a comparator function with respect to the comparison between sensations of central (cerebral) origin versus sensations of peripheral (environmental) origin. This particular comparison has been questioned and discussed in detail by Kromer [8,10], who instead suggested a comparison between bodily and environmental stimuli. Such a comparison refers to embodiment of self-consciousness (compare to: [3,15,16]) and highlights the special features of bodily sensations. Actually, bodily sensations will be perceived by any individual as own because any part of the body is experienced in the context of the rest of the body. Any change over time or during illness, even mental illness, will take place still embedded in this continuity of the complex scenario of interlinked, bodily sensations [8,10]. In contrast, input from the environment or sensations originating inside the brain (imaginations) are objects of forgetting (compare to patients suffering from an identity loss; see next paragraph). They are random, not reliable and therefore a poor basis of self.

In contrast to a computerized machine, the living brain's software is identical with its hardware [17]. Although the biological system is, due to its neuronal plasticity [18-20], enormously efficient and powerful, it may not allow for the development of self-consciousness without the comparative representation of bodily versus environmental stimuli as mentioned above. The body as a reference system is indispensable (embodiment). In support of an embodied self it may be noted that, by fertilization, two cells without any experience of "self" fuse, divide and grow up to a body which only then and in the course of time develops consciousness. The body is first, the mind is second and a function of the physical matter. Actually, perception of the environment is always paralleled by perception of one's own body, at least on a limited scale. As already discussed previously [10], the importance of the body as the relevant reference system for the organism's "self" is further supported by patients who suffer from a severe identity loss. These patients do not remember their autobiography but still experience themselves as individuals facing their environment. The obvious explanation is the comparative, cerebral representation of bodily versus environmental input, representing the fundamental mechanism of self-awareness.

Irwin [21] mentioned in his short review "What Current Theories of Consciousness are Missing" a number of powerful models of consciousness such as The Dynamic Thalamocortical Core, The Global Neuronal Workspace, The Higher Order Thought, and the Integrated Information Theory. Irwin then noted that none of those models does specify "the brain mechanism for monitoring the functional events that become conscious". But also Irwin failed to identify the fundamental gap as previously addressed [9]. All of the models mentioned by Irwin no doubt provide important input to the discussion on consciousness. However, all of them only refer to the neuronal mechanisms behind the crucial function, namely the comparative representation of bodily versus environmental stimuli, based on source-monitoring. This aspect is the one that current theories of consciousness are really missing, at least to a significant extent.

Artificial Systems: Their Deficiencies

Imagine one of your legs had been replaced by a prothesis and you touch it with your fingers. Even if it had a surface structure quite similar to your living leg, you will immediately recognize

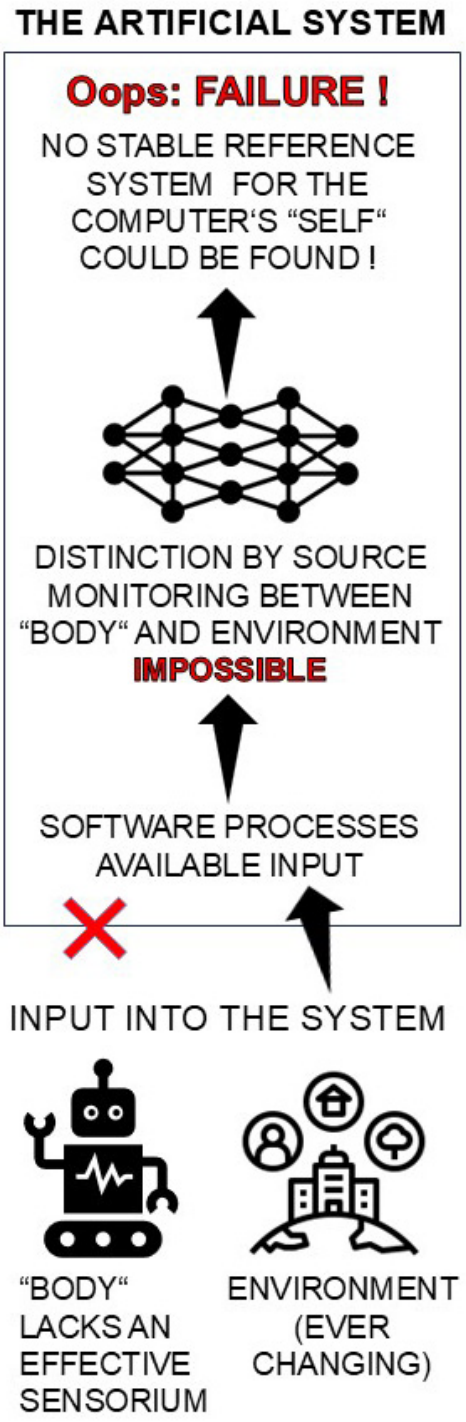

Figure 2. The artificial system lacks any "body" equipped with an effective sensorium and bidirectional communication with its "brain". Therefore, no stable reference system for the computer's supposed self is available, and self-consciousness will not emerge.

it as a foreign part not belonging to you. This is because the prothesis does not send to your brain any information about the touch of your fingers. It does neither have any sensorium nor any connection to your brain. Now your fingers touch your living leg. No surprise, you will perceive it as your own leg. Not only do the fingers feel the skin, but the skin receives and sends back to your brain the touch of your fingers and, together with the proprioception sensing the leg's position in the three-dimensional space, this complex information tells your brain "it's ME!". Actually, in the living organism, the information flow is bidirectional. The skin, the bones, the skeletal muscles and tendons are intensely supplied with sensory organelles and nerve fibers penetrating the entire tissue, which also applies to the viscera. While the body receives signals from the central nervous system (CNS), it also sends signals back to the CNS which are there processed by neuronal networks and interlinked with all the other bodily sensations. The different parts of the body are thereby perceived as parts of the whole.

The above example of the prothesis reminds of the conditions faced in an artificial system. Even if there were sensors installed to measure, for example, the temperature of the hardware's material or the spatial position of a moving part of the robot's body, those thrifty, insufficient measurement data would be registered by the software as belonging to a dead material. While the body's living tissue does actively take part in the conversation with the brain, the computer's dead material may (theoretically) be contacted by sensors from outside in order to read out particular parameters. But it can not actively communicate with the software at any even somewhat sufficient level, at least not when judged on the basis of the current status of technology. This is illustrated in Figure 2.

Any computer program per se only provides the tools for processing information, but does not provide any steady, individual reference system a computer's "self" could rely on. This would require that the "body" (hardware, encasement with functional parts) of the artificial system be equipped with a sensorium of high complexity with bidirectional information flow, comparable to the biological system. Moreover, the artificial system would have to be able to integrate all these input signals such that they are "experienced" as all belonging to one and the same individual entity. This has been regarded hard (if at all) to accomplish, and it was predicted that those functions might be even meaningless in a dead material [8].

In contrast to the above conclusion, Holland [22] reported on the outcome of a workshop held in 2001 and titled "Can a machine be conscious?". He noted that, of around twenty high-profile scientists, all but one felt yes, it can. But the workshop left open how this might be achieved. Holland addressed in his summary a few potential features of consciousness which lighted up in some of the contributions, such as "capacity for imitation" (Susan Blackmore), "functional consciousness" (Stan Franklin), "internal modelling" (Holland and Goodman), or "inner voice" and "re-entrant mapping" (Luc Steels). Going a step further, Baars and Franklin [23], while referencing to the Global Workspace Theory, proposed "that machine consciousness may be produced by [...] adaptive algorithms running on the machine". But neither this approach, nor the features mentioned above, or the implementation of neuromorphic technologies [24,25] will even touch the crucial point, which is the mechanism by which the organism is able to recognize its own, bodily existence facing the environment. At least as far as the emergence of self-consciousness is regarded, all of those features and technologies gain relevance only after source monitoring between body and environment has been successfully implemented.

Outlook: Bad Cards For The Computer

Any neuronal or software mechanisms, as complex they may ever be, only provide the tools for generating self-awareness which may, in essence, be reduced to a comparative, cerebral

representation of the own body versus its environment. However, the machine lacks any body that communicates with the machine's software in a complex enough manner (if at all) in order to be perceived as "own". An embodied self will therefore not develop. In accordance with the above, Dehaene et al. (26) stated that "current machines are still mostly implementing computations that reflect unconscious processing in the human brain". Will that be the end of it, will the two NEVER meet? Although the issue is still controversial in the scientific community, the conclusion may be as simple as probably inevitable: Yes, based on the fundamental considerations outlined above, the biological consciousness may never meet its artificial counterpart because the latter will, in all likelihood, never exist.

References

1. Garmroudi A, Tushar Md.A.K., Liu C., Li Z. Biohybrid living robotics: A comprehensive review of recent advances, technological innovation, and future prospects. Npj Robotics. 2025; 3(43): 1-14. https://doi.org/10.1038/s44182-025-00056-x
2. Aru J, Bachmann, T. Still wanted – the mechanisms of consciousness! Frontiers in Psychology. 2015; 6 (5): 1-3. https://doi.org/10.3389/fpsyg.2015.00005
3. Krauss P, Maier A. Will We Ever Have Conscious Machines? Frontiers in Computational Neuroscience. 2020; 14 (556544): 1-14. https://doi.org/10.3389/fncom.2020.556544
4. Blum M, Blum L. A Theoretical Computer Science Perspective on Consciousness. Journal of Artificial Intelligence and Consciousness. 2021; 8 (1): 1-42. https://doi.org/10.1142/S2705078521500028
5. Baars BJ. Understanding Subjectivity: Global Workspace Theory and the Resurrection of the Observing Self. Journal of Consciousness Studies. 1996; 3 (3): 211-216.
6. Zeman AZJ, Grayling AC, Cowey A. Contemporary theories of consciousness. Journal of Neurology, Neurosurgery, and Psychiatry. 1997; 62: 549-552.
7. Maia TV, Cleeremans A. Consciousness: converging insights from connectionist modeling and neuroscience. Trends in Cognitive Sciences. 2005; 9 (8): 397-404.
8. Kromer W. Is Consciousness A Mystery? A Simplified Approach to Pinpoint the Basic Nature of Consciousness. Journal of Psychiatry and Psychiatric Disorders. 2022; 6 (3): 196-202. https://doi.org/10.26502/jppd.2572-519X0162
9. Kromer W. The Amazing Gap in Consciousness Research. American Journal of Neurology Research. 2025; 4 (1): 1-3. https://doi.org/10.52106/2837-7761.1021
10. Kromer W. Tracing the Basis of Self-Consciousness Back to the Essential. International Journal of Psychiatry Research. 2025; 8 (5): 1-6. https://doi.org/10.33425/2641-4317.1231
11. Johnson MK, Hashtroudi S, Lindsay DS. Source Monitoring. Psychological Bulletin. 1993; 114 (1): 3-28.
12. Vinogradova OS. Hippocampus as a comparator: role of the two input and two output systems of the hippocampus in selection and registration of information. Hippocampus. 2001; 11 (5): 578-98. https://doi.org/10.1002/hipo.1073
13. Zaadnoordijk L, Besold TR, Hunnius S. A match does not make a sense: on the sufficiency of the comparator model for explaining the sense of agency. Neuroscience of Consciousness. 2019; 5 (1): 1-11. https://doi.org/10.1093/nc/niz006
14. Kunzendorf RG. Source monitoring as an explanation for the illusion of "self as subject". Psychology of Consciousness: Theory, Research, and Practice. 2022; 9 (1): 64-77. https://doi.org/10.1037/cns0000219
15. Prinz J. Is Consciousness Embodied? In: Robbins P, Aydede M, eds. Cambridge Handbook of Situated Cognition. Cambridge University Press 2009; 419-436.
16. Newen A. The Embodied Self, the Pattern Theory of Self, and the Predictive Mind. Frontiers in Psychology. 2018; 9 (2270): 1-14. https://doi.org/10.3389/fpsyg.2018.02270
17. Laydevant J, Wright LG, Wang T, McMahon PL. The hardware is the software. Neuron. 2024; 112: 180-183. https://doi.org/10.1016/j.neuron.2023.11.004
18. Appelbaum LG, Shenasa MA, Stolz L, Daskalakis, Z. Synaptic plasticity and mental health: methods, challenges and opportunities. Neuropsychopharmacology. 2023; 48: 113-120. https://doi.org/10.1038/s41386-022-01370-w
19. Gazerani, P. The neuroplastic brain: current breakthroughs and emerging frontiers. Brain Research. 2025; 1858 (149643): 1-15. https://doi.org/10.1016/j.brainres.2025.149643
20. Mousley A, Bethlehem RAI, Yeh F-C, Astle DE. Topological turning points across the human lifespan. Nature Communications. 2025; 16 (10055): 1-17 https://doi.org/10.1038/s41467-025-65974-8
21. Irwin LN. What Current Theories of Consciousness are Missing. Neurology & Neuroscience. 2023; 4 (4): 1-4. https://doi.org/10.33425/2692-7918.1059
22. Holland O. Editorial Introduction. Journal of Consciousness Studies. 2003; 10 (4-5): 1-6.
23. Baars BJ, Franklin S. Consciousness is Computational: The LIDA Model of Global Workspace Theory. International Journal of Machine Consciousness. 2009; 1 (1): 23-32.
24. Jung B, Kalcher M, Marinova M, Powell P, Sakalli E. Neuromorphic Computing – An Overview. Cognitive Science Student Journal. 2023; 7: 1-10
25. Muir DR, Sheik S. The road to commercial success for neuromorphic technologies. Nature Communications. 2025; 16 (3586): 1-12. https://doi.org/10.1038/s41467-025-57352-1
26. Dehaene S, Lau H, Kouider S. What is consciousness, and could machines have it? Science. 2017; 358: 486-492.